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THE BLACK OR STEM RUST OF WHEAT

A POPULAR ACCOUNT OF THE NATURE, CAUSE AND PREVENTION OF GRAIN RUST

BULLETIN No. 33
SECOND SERIES

Dr. a. J. Gossow with the author's compts. H. T. Gussow

MARCH, 1917

Published by the direction of the Hon. MARTIN BURRELL, Minister of Agriculture.
Ottawa, Ont.

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Ottawa, May 1, 1917.

The Honourable,
The Minister of Agriculture,
Ottawa.

Sir:—

I have the honour to submit herewith the manuscript of Bulletin No. 33, of the Second Series, entitled "The Black or Stem Rust of Wheat", it being a popular account of the nature, cause and prevention of the disease.

This is a very timely publication on the subject of rust and is written in such a popular style that its appearance at this time should be most useful to the farmers of the prairie provinces. The bulletin affords a good idea of what rust is, and gives, in concise form, such information as is at present available on how to guard against its ravages.

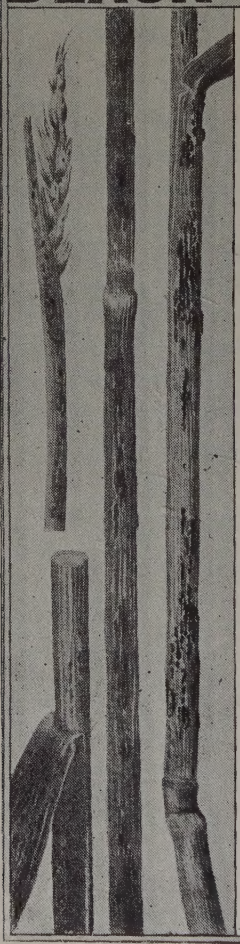
I would recommend, therefore, that the printing of this bulletin be proceeded with as soon as possible.

I have the honour to be, Sir,

Your obedient servant,

J. H. GRISDALE,
Director, Dominion Experimental Farms.

BLACK OR STEM-RUST OF WHEAT



DOMINION OF CANADA
DEPARTMENT OF AGRICULTURE

CENTRAL EXPERIMENTAL FARM
J. H. GRISDALE, B. AGR.
DIRECTOR

DIVISION OF BOTANY
CIRCULAR N° 12

GRAIN RUSTS are the cause of heavy local losses every year, in widespread epidemics, as in 1904 and 1916, the total loss to the country may amount to millions of dollars. Black, or more correctly, Stem Rust, is the most destructive of all rust diseases in Canada, as it chiefly affects the important wheat crop; but it also attacks oats, barley and rye. Stem Rust has two stages on grain, the red and the black stage; another stage in the life history of this rust occurs on the Barberry. For a more detailed account of this disease consult the Bulletin on Black or Stem Rust of Grain, published by this Department (Publications Branch). The losses from rust may be considerably reduced by closely observing the following principal recommendations.

1. Choice of Land Avoid wet land or provide thorough drainage, which increases vigour and yield Vigorous plants are less liable to attack

2. Seed Bed The careful preparation of the seed bed is an important consideration, a warm, well ventilated soil, with even smooth surface encourages uniform germination, increases the root system, and aids rapid growth to early maturity. Any cultural method that tends to increase vigour and strong growth will lessen losses from rust

3. Rotation Crop rotation increases vigour and yield of all crops. Continuous wheat cropping produces weedy farms, wastes soil fertility and favours disease

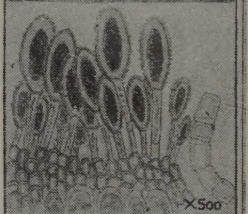
4. Weeds Weeds impoverish soil. Impoverished soil is undesirable for any crop. Practise thorough weed eradication, thus aiding the grain crop.

5. Seed All seed must be treated for smut, but no known method of seed treatment will check rust. *Of foremost importance, be the soil or weather conditions what they may, is the use of superior seed grain of strong germination. Shrivelled or light seeds, old seed grain of low germination or frosted grain should not be used*

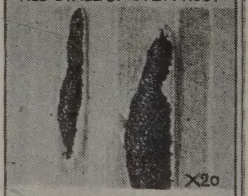
6. Early Sowing *is highly desirable. Early sown grain often escapes rust injury altogether, and, generally speaking, is far less liable to rust attack.*

7. Early Varieties *The choice of early maturing varieties, otherwise satisfactory as to yield and quality, is, therefore, recommended* Such varieties are generally past the vulnerable stage at the time rust infection of late varieties becomes general. Do not pay fancy prices for so called "rust proof" varieties. No variety is rust proof.

8. The Barberry The relation of the Barberry to Stem Rust has long been established. It is most essential that the shrub be exterminated throughout the grain growing areas of the Dominion. It is undoubtedly a contributory factor to rust and, therefore, most undesirable.



RED STAGE OF STEM-RUST



BLACK STAGE OF STEM-RUST

BLACK OR STEM RUST OF WHEAT

INTRODUCTION

This account has been prepared, partly to amplify the illustrated coloured poster on the same subject being issued by the Department, and partly to meet the many inquiries received in this laboratory, relating to the nature and cause of grain rust, about which there exist among farmers and others not always correct theories.

It is thought desirable to deal with the subject in this preliminary account, in a manner easily understood by the practical farmer whose time and facilities do not permit him to enter deeply into a subject of—after all—so highly technical a nature. The term "rust" is familiar to the farmer, but our experience has shown that there are a large number of farmers who only know the term and not really the disease; this is demonstrated every year by the many samples and inquiries relating to rust which are received, but which on examination bear no resemblance to the disease.

SEVERAL DISTINCT KINDS OF RUST

It is an established fact that there exist several kinds of grain rust, just as different from each other as wheat differs from oats or barley. Moreover, the peculiar mode of development of our commonest grain rust—the black or stem rust—during certain periods in which it may differ in appearance to a remarkable degree, has given rise to the popular belief that there are two kinds of rust—the Red Rust and the Black Rust—of which two the latter alone is popularly regarded as seriously injurious.

The truth, however, is that both the so-called red and black rust are merely stages of the same fungus causing this destructive disease.

The disease commonly known as rust is caused by extremely minute parasitic plants which live upon the grain plant and the resources of food manufactured by this plant for its own sustenance. This utilization of food by the small but very vigorous parasite often causes serious injury to the plant upon which it lives, or which acts however involuntarily as its host; hence the term "host plant" which is now commonly used in referring to similar existing relations.

The rust-causing plants are so small that a hand lens is barely sufficient to make out the most prominent characters. By means of the powerful lenses of a microscope, the characters of the various kinds of rust become so prominent that the differences between them are more or less readily distinguished, and these small plants may then be seen clearly to be as different as wheat, oats and barley are seen to differ with the naked eye.

When wheat, oats or barley is affected by rust, the first symptoms that may be recognized are small yellow, orange, red, brown or black circular or linear spots covering leaves, stem, and ears of the host plant. The more severe the attack is, the more numerous are the spots; a few spots are present every year on growing plants, the disease being rarely absent.

These spots are most characteristic; they do not consist of dead areas of the portions attacked, they are not thinner than the normal thickness of the leaf. For instance, they do not resemble pin pricks similar in nature to injuries due to sucking insects, but they are at an early age slightly raised minute blisters or longish narrow wales, as if "something" within the interior of the leaf or other parts attacked were making an effort to push through the skin (technically the epidermis or cuticle) of the leaf. Indeed, this is exactly what occurs. Before the yellow, red, orange, brown or black wales become visible, they have already been present in the leaf or other tissues, slowly gathering and pushing against the leaf surface with an ever increasing force, until the skin is burst and what was formerly covered and hidden by it appears on the surface in the form of various coloured spots. This process can be easily watched by an interested observer in possession of a fairly strong hand or pocket lens. *

The colour of the spots is due to what may be described as a fine powder—in reality the seeds of the rust plant. Technically, one speaks of plants of this kind as "fungi" and of their seeds as "spores."

The colour is to some extent a guide either to the stage of development reached by any one species of rust, or to the peculiar kind of rusts present. Thus pale yellow orange cushions are nearly always associated with yellow rust, brownish spots with brown rust, black spots or stripes with black rust. These are very popular distinctions; there are other features visible under the microscope which clearly separate one fungus from the other.

THE CAUSE OF RUST AND THE INFECTION OF THE WHEAT PLANT

We shall now consider how the fungus originally entered the interior of the leaf or stem of the host plant, what took place while within it and what will further happen when it has broken through the skin.

The most common and injurious of all rusts is undoubtedly the so-called "Black or Stem Rust" which is caused by the minute parasitic fungus technically known as Puccinia graminis, Pers. This rust is found on wheat, oats, barley, rye, and a large number of wild and cultivated grasses. The symptoms may be observed on any part of the plant with the exception of the root.

Black Rust is responsible for nearly all the losses to grain in Western Canada. Occasionally epidemics such as that of 1916 occur, which cause a loss of hundreds of millions of dollars to the national wealth. Its life history is therefore fully discussed in the following pages. Farmers are most concerned with this rust, as it is so destructive to grain, though it does not actually commence its life cycle on grain, but for a better understanding we shall start our consideration with this plant.

* The possession of a pocket lens is a great asset to the farmer; with it he can often recognize very minute enemies, which are so dangerous because so minute, and not visible to the naked eye. A very excellent lens for use is the "20 diameter Coddington," manufactured by Messrs. Bausch and Lomb, Rochester, N.Y., and sold in Canada for about $1.50. In using such a lens, hold the object to be examined in the left hand, allowing the light to fall upon it, then hold the lens with your right hand flush on the object, keeping the eye about 4—6 inches distant, then begin very slowly to raise the lens away from the object, keeping your eye steadily fixed on the centre of the lens until the object to be examined appears very prominent and so much enlarged that in the case of rust, all the details described above become clear and conspicuous. It is well to try this proceeding on the print of a book or newspaper.

THE RED OR SUMMER STAGE OF STEM RUST

We have already described in a general manner, the process of the life of the fungus until the spores appear through the ruptures in the skin. The spore-masses that appear at first are rusty red in colour, hence the popular term "Red Rust" (see coloured poster on Black or Stem Rust of Wheat, which is reproduced in black and white in this issue, left panel centre stem and left bottom stem showing red rusty spots).

The rust spots may be so numerous that when a leaf is drawn between finger and thumb they will become covered with reddish brown dust. At the time of threshing last year's crop, the amount of rust spores flying about in the air was so enormous that quantities could be scraped off the coats worn by the men serving the machine.

This red form of spores is generally referred to as summer spores, because when they are first noticed it generally is during summer, but some of them may be found in fall on late maturing wheat, indeed instances are known of some having passed through the winter.

These spores are seeds inasmuch as they have the capacity to germinate, only they do not germinate in the soil and grow there, but do so instead right on the surface of the leaf or stem of the same plant, or of neighbouring plants or plants some considerable distance away, for it is easily understood that the spore dust must be blown about by the wind, which in fact does occur and is one of the means of the spread of the disease.

Rust spores are produced in these spots by millions (compare coloured poster right hand, upper half "Red Stage of Stem Rust". The uppermost square shows a small piece of leaf tissue with two rust spots enlarged twenty times. Here, the rupture of the cuticle is easily seen, as well as the red dust bursting through the ruptures composed of the red or summer spores referred to. Immediately below this square, these spores are shown enlarged five hundred times. As will be seen, they are attached to short colourless stalks and are of oval shape with golden yellow contents and a thin-walled membrane, covered with very minute prickles).

Every spore produced is capable of germination under suitable conditions. Nature is so lavish and generous in the production of seeds and spores that, if every seed or spore would develop into a plant, in the course of a very few years there would be left only the most persistent plant that had succeeded in crowding out all the others. It is, therefore, safe to say that most of the seeds or spores produced do not find the necessary conditions to start into life.

Seeds do not grow on rocks, do not germinate without moisture. It is just the same with fungus spores. They are far less securely protected from drought than seeds, and millions dry up and die. Moisture is indispensable for their germination, though it be only what we term the humidity of the atmosphere. During dry, windy weather, rust epidemics do not develop, but we know that a few still, humid days miraculously favour the spread of rust. Now during the summer under favourable conditions, the spores germinate and produce a very fine "rootlet" which penetrates into the interior of the plant. In the tissues and cells composing the host plant, the rootlet finds ready-made

food in plenty, similar to what occurs when a seed is planted in fertile soil. The original "rootlet" now branches and ramifies in all directions, permeating the cells of the host plant, which during this process does not appear to be injured. When finally the fungus plant has existed in this condition long enough, it produces from its mass of cells a number of primary spore-cushions, within the interior of the host plant. These grow in size and struggle for an exit, which is only through the skin or cuticle of the plant. This cuticle at first bulges out and finally bursts or ruptures, when a mature crop of spores appears on the outside. This process takes from eight to ten days, i.e., from germination to spore production, and continues throughout the summer as long as there are to be found green leaves of cereals or grasses to afford a suitable medium for their growth and development. Thus far, we have been dealing with the summer stage, or what is termed "Red Rust," and erroneously considered to be a disease different from the later stage.

THE BLACK OR WINTER STAGE OF STEM RUST

The summer stage is soon followed by another and that on the same host plant and in close association with the spots produced by the summer stage. This new form is termed winter stage, but is popularly referred to as "Black Rust." The term winter stage is not quite correct either, since this stage may appear as early as August, but, generally speaking, the term winter stage is used in view of the fact that this new type of spore does not germinate until the following spring.

When the red rust stage changes into the black rust stage the spots become decidedly more linear in shape and appear as long black sooty stripes. (Compare coloured poster left panel the affected part bearing an undeveloped ear and the culm to the extreme right of panel showing black stripes). When this stage is reached, the greatest damage has been done and the fungus is aware that the life of the host plant is doomed, hence, according to nature's law, the fungus must now look after its own perpetuation which it does by the production of specially thick-walled winter spores, which are so protected as to withstand even very severe winters. (Compare coloured poster right panel, two lower squares, of which the upper shows the change in colour that has taken place. Note no dispersal of spores in this condition, but compact crusts composed of winter spores. Below, the square shows winter spores enlarged five hundred times. In shape they will be seen to differ very considerably from the summer spores, as well as in colour).

RED STAGE AND BLACK STAGE OF STEM RUST BELONG TO THE SAME FUNGUS

It is again stated here that while to the layman the red stage appears to be so absolutely different from the black stage, which as far as structure is concerned, is quite correct, yet the former is merely an earlier stage in the life history of Stem Rust, while the latter is the final or mature stage. This is no rare occurrence in fungi, many of which have quite different summer forms and spores from those of the winter forms; some indeed, produce still more

kinds of spores, all of which are merely stages in their development towards maturity. In insect life of course, everybody is quite familiar with the remarkably different forms and shapes and indeed modes of life through which many of them pass in the course of their life cycle. Every schoolboy is nowadays familiar with the life history of an ordinary butterfly or moth. The caterpillar, chrysalis and adult insect are merely stages of the same individual insect. This example may serve as an illustration explaining the close relationship existing between the various stages of the rust fungus.

ACTION OF THE FUNGUS ON THE HOST PLANT

It should be fully understood that the damage done to the grain crop is the result of the strictly parasitic mode of life of the fungus as previously indicated. A sound wheat plant consists of a large number of cells and sap-conducting vessels, all of which are required to perform their individual function in storing, supplying and making available food supplies to the plant, to bring it to maturity, that is, to enable it to ripen its seeds which are the "grain" of commerce. A slight rust attack involves only comparatively few individual cells of the host plant and the damage is slight. But when the attack is severe the plant suffers much more and may be killed before any grain is produced. This process might be described as follows. The grain, during its development, gradually becomes filled with food reserves which it takes from the growing plant. If a fungus uses part of this supply, the grain suffers proportionally. The result is a more or less shrivelled, small and immature grain. In bad rust years, an acre may yield a small quantity of grain, but this is generally as useless for seed purposes as it is for milling. Thus, it will be seen that the loss from a rust epidemic is not only an immediate one, owing to loss of yield, but there is, as a further consequence, a lack of plump, vigorous seed grain.

THE RELATION OF STEM RUST TO THE BARBERRY

It was stated in the beginning that the subject of grain rust is one of a highly technical nature. The life history of this fungus is certainly a most complicated one as far as our present knowledge goes, indeed there are some phases which, though familiar to the close observer, are nevertheless not thoroughly understood.

In the foregoing sections we have discussed the life of the rust fungus as it is passed on the wheat. We must now consider another phase of the life history of the Stem Rust, which occurs on quite a different host plant, viz., the Barberry. In passing, let us recall the reference already made to the remarkable but different modes of life found in the life cycle of one and the same insect, giving as a further example here, the common dragon fly, which passes one stage in water and another in the air.

Before discussing the importance of Canadian conditions in relation to this change of host plants on the part of the fungus, we shall briefly relate how it occurs.

The winter spores of rust germinate in spring, but even though they may be sown thickly on the surface of growing grain plants, they have not been known at any time to push a 'rootlet' through the pores of the epidermis like the summer spores. They cannot, under any circumstances, directly infect any of the cultivated or wild plants generally subject to rust. What could be accomplished easily with the summer spores on wheat plants could not be successfully carried out with these winter spores, although they were tested as to their germinative power. What became of these winter spores and what purposes they fulfilled was long a matter for speculation.

It may, at this stage, be of general interest to mention the popular belief regarding the common barberry in Europe. Practical farmers as early as the middle of the 17th century, regarded the barberry as having a close relation to the rust of grain. This common shrub was looked on as having a mysteriously injurious influence on grain. Since that time, this belief has been reiterated again and again, and indeed as early as the year 1660, the municipality of Rouen (France) issued a decree ordering the destruction of this shrub. Nearly one hundred years later the State of Massachusetts promulgated an order demanding the destruction of all barberry bushes. In 1776 Withering, a well known naturalist in England, recommended "That this shrub should never be permitted to grow in "corn" (grain) lands, for the ears of wheat that grow near it never filled." And so, owing to what appears as a somewhat popular superstition, the barberry was regarded as a menace to grain culture.

It was not until the latter half of the 19th century, i.e. in 1865, that Anton de Bary, a famous German botanist, determined by scientific experiments that the life cycle of this rust was continued on the barberry. He found that the winter spores of Stem Rust on wheat produced, on germinating in spring, another form of spores, which in their time germinated on and entered into the leaf tissues of the barberry.

The infection produces very prominent, bright red-coloured spots on the leaves of the barberry, the spots often showing a pronounced yellow margin. (Compare coloured poster top panel, showing the shrub barberry in flower and fruit and four leaves bearing the bright coloured spots resulting from an infection with winter spores from stem rust of wheat). In greenhouse experiments conducted at the Central Experimental Farm, infections of barberry leaves were produced from over-wintered wheat rust-spores in some 12 days. The spots soon assumed a very bright red colour, though only of the size of a pin prick at first. They began increasing in size, until after some four weeks from infection there was produced a crop of spores in minute cluster-cups pushing through the lower surface of the barberry leaves. Under favourable conditions, however, the time required for this stage might be much less. Reference should be made here also to the production on the upper leaf surfaces (corresponding to the spots) of small droplets of a sugary, gummy substance, which contain very minute sporelike bodies, technically known as spermatia—about the function or purpose of which, up to date, nothing is known. The spores produced in the cluster-cups of the barberry again differ in shape and size from any described before. These spores refuse to germinate on the bar-

berry, but when sown on the leaves of a grain crop, the result is the production of the first crop of summer spores of stem rust already described in detail.

LIFE HISTORY OF STEM RUST OF WHEAT IN SHORT

This is to recapitulate briefly the life history of grain rust. On the leaves of barberry are produced early in the year "spring spores." These do not infect the barberry, but go on to the grain producing "summer spores" followed later on by "winter spores" on the same host. The winter spores hibernate on the stems of cereals and other grasses; they cannot cause a direct infection of the growing grain plant, but infect the barberry, and thus the life cycle is completed.

THE ROLE OF THE BARBERRY IN CANADA

The barberry (Berberis vulgaris, L.) is not a native shrub in the Dominion of Canada. It has been introduced from Europe, because of its hardiness and somewhat ornamental value. It is by no means even a common ornamental shrub, such as lilac for instance, but occurs in private grounds and may have escaped from cultivation, at any rate in the Eastern section of the country.

The position of the barberry in the life cycle of the grain rust cannot be disputed. This shrub certainly serves as an intermediary host plant, but although the discovery is primarily of scientific value and no doubt of economic importance in countries where the barberry grows wild, it does not solve or even bring nearer solution the great problem of wheat rust in Canada.

Yet it is a fact that the barberry occurs in Canada, and moreover, it is infected every year that we have been able to observe personally. In Manitoba we observed infections of barberries to such an extent that the shrubs appeared to be of a pronounced golden yellow colour from spore-cushions.

It is, however, a fact deserving attention that in Manitoba and the other important grain growing provinces, Saskatchewan and Alberta, the barberry, while not entirely absent, is an apparently negligible factor, only very few bushes occurring in these regions.

The question confronting the scientific advisors on such subjects, particularly under conditions similar to those prevailing in Canada—which are known to exist in India, Australia and elsewhere—is: If the barberry alone is responsible for the perpetuation of grain rust, and if, without the barberry, grain rust, that is, stem rust, will go out of existence, would it not be the easiest matter in the world to save the immense losses from grain rust by the destruction of this comparatively worthless shrub?

This is just the point which has been the subject of controversy all over the world and on which only very few reliable and conclusive data exist, if any. The complete eradication of barberries has not so far been carried out in any country and not until this has been done and the effect of such action on grain rust has been recorded for at least a decade, can this question be regarded as satisfactorily answered.

In the report of the Dominion Botanist of Canada for 1911, p. 239, the present status of our knowledge of rusts was briefly summarized, and it was

stated that it had been found, in Denmark for instance, that the compulsory destruction of barberry has not brought a reduction in the severity of rusts. This statement was eventually read in Denmark, and we are indebted to Dr. J. Lind of the Phytopathological Experimental Station, Lyngby, Denmark, for a letter in which he refers to this statement, explaining that:

> "Puccinia graminis is quite perceptibly disappearing in Denmark year by year to the same degree as we get rid of the Berberis, and we are very well satisfied with the results of the Berberis Act."

This communication contained important information of a more definite character than any we had been able to secure previously. We thought it, however, desirable to seek the opinion of another Danish plant pathologist and communicated with Dr. F. Kölpin Ravn of the Pathological Museum of Kopenhagen. He very courteously writes us:

> "In your letter you desire to know what my personal experience has been concerning the extermination of barberry bushes in this country. I have been able very often to observe early outbreaks of Puccinia graminis on rye and oats; in all such cases—without any exception—we have been able to find some barberry bushes near by; and some years after the removal of these bushes these early outbreaks of rust had disappeared.
>
> Several of the Local Advisers in Plant Culture carried on a systematic fight against the barberry bushes, as required under the Act. And at present the early—and only dangerous—outbreaks of black rust are rarely reported. I may add that the farmers have practised for some recent years sowing spring grain earlier than before, which further helps in the fight against the rust. I think, therefore, that the present very slight infections by Puccinia graminis are the results of the two named factors taken together."

We regard the barberry in Canada as a known contributory factor to grain rust. In this attitude we are supported by practically every scientific observer on this continent and we, therefore, would strongly recommend the complete extermination of this shrub at any rate throughout the regions of the Dominion principally devoted to grain growing. There are other factors contributory to the severity of grain rust over which we have no control—weather conditions for one—but the question of the barberry is one that might easily be overcome. It is one of the principal precautionary measures that should be taken in the interest of the grain-producing regions throughout the Continent of America.

One of the most ornamental shrubs of the genus Berberis is the very small leaved Japanese barberry (Berberis Thunbergii, D.C.) which is not attacked by rust and may be safely planted.

POSSIBLE PRECAUTIONS TO REDUCE LOSSES FROM GRAIN RUST

No specific remedy is known at present that will control grain rust. Seed treatment as practised successfully for smut diseases of grain has not

shown any reduction of losses from rust. The reason must be apparent to those who have followed the description of the life history as given in the preceeding chapters. Even though the seed grain may exhibit winter spores, these cannot infect the wheat plant, and whether they are alive or have been killed by special treatment does not much matter. The question as to whether the seed grain acts as a carrier for rust is one that has been discussed for many years; while this possibility is not totally out of the question, it is certain that no treatment that has been tried gave any satisfactory results.

The above statement should not convey a wrong idea, viz.—that it is useless to attempt the control of rust. Happily, careful field studies, laboratory investigations and confirmation of results thus obtained by experiments under field conditions, have placed at our disposal the knowledge of a number of factors greatly encouraging the severity of the disease or rendering the crop more liable to attack or destruction. The careful elimination of such factors, which are within the control of the farmer, will naturally secure beneficial results.

Indeed, the last great epidemic in Canada once more confirmed the correctness of certain precautionary measures that can be suggested. On examining the area of wheat most seriously affected by the rust, it was found that single fields surrounded on all sides by fields badly smitten by the rust, stood out erect and affected to a considerably lesser degree than those close by. While the latter fields were not considered worth cutting because of the severe attack by rust, the others yielded often as high as 21 bushels per acre, some less and some even more. This was one of the most striking lessons of the rust epidemic and had all farmers known the reason and taken the necessary precautions, the losses from grain rust might have been very considerably reduced.

In brief, the reasons for the escape from rust of some of the fields mentioned were:

Early sowing, which was by far the most satisfactory; the use of early maturing varieties which had in some cases matured the grain before the fungus had done its destructive work; and sowing on high or sandy lands, or a combination of these three points together.

From observations made in the Dominion of Canada, which are supported by the recommendations made in almost every wheat-growing country in the world, we would strongly urge all grain growers to follow the precautionary measures set forth below, when they can be assured that, even in the years of serious epidemics, the losses from rust may be considerably reduced. Moreover it is wise to be prepared for the recurrence of rust epidemics at any time.

1. **The choice of land.** The selection of good wheat land on the prairie is not generally a difficult matter or one which requires special care, since, generally speaking, the available land is very similar in nature and usually suitable for wheat-growing. In some localities of rolling prairie, or prairie with sloughs and ravines, attention must be paid to the selection of wheat land. It is most important to avoid the use of wet land unless such is carefully and correctly drained. Wet land usually forms a cold bottom for wheat and

in many cases cannot be worked very early. This delays sowing, besides, owing to cold and wet, the germination of the grain is delayed. Wet soils also are generally lacking in air; aeration of the soil is a great aid to the development of a profuse root system and a strong, vigorous plant in consequence.

2. The Seed Bed. Provided good land is available, if the preparation of the seed-bed is not attended to with care and patience, the benefits derived from suitable land alone will be greatly reduced. The preparation of the seed-bed should aim at that degree of mellowness of texture in which the seed may find most encouragement from aeration, warmth and moisture. Therefore, any cultural practice by which an even, smooth surface is obtained, is strongly recommended.

3. Rotation. Continuous wheat cropping wastes soil fertility, increases the growth of weeds and is most injurious to the vigorous growth of wheat. Slow growth delays maturity and late maturity is disastrous in years of rust and also exposes the crop to frost injury.

4. Weeds. Weeds impoverish soil besides using up soil moisture that should be retained for the wheat. Thorough weed eradication is essential to the success of any crop. It is useless to expect a full crop of wheat from a weedy field, and besides, the yield of sound grain is contaminated by weed seeds.

5. Seed-Grain. A matter of much greater importance than the variety of wheat most suitable in any one particular region is that the seed grain be composed of the heaviest, plumpest kernels possible. All seed must be treated for smut every year, but this treatment is well-known to have no effect on the grain rust. In years following severe rust epidemics or where the grain was much injured by frost it is necessary to exercise particular precautions to remove all shrivelled and light seeds. To sow grain containing a large percentage of these inferior seeds, is really to invite loss since the weak plants resulting from such seed show an increased predisposition towards disease. Needless to say, old seed grain of low germination or frosted grain should not be sown for the same reasons. The seed to use should be of strong and even germination. A small sample of wheat is easily tested by the farmer himself. For this purpose, use two soup plates and place a small number of grains between folds of moist blotting paper or pieces of uncoloured flannel and cover same with another plate. If this primitive germinating apparatus is kept in a warm place, the seeds will have sprouted in four or five days. A sample showing 70 and more seeds sprouted in this time, out of 100, is considered to be of strong germination. To sprout all seeds may take a week or more. A sample showing, after four or five days, only a germination of 20 or less, cannot be considered of strong germination, although all grain may eventually have sprouted after a week or so. The more rapid the energy of the grain, the more suited it is for sowing and producing even, strong plants.

6. Early Sowing. Early sowing of the seed is one of the most important factors to prevent serious losses from rust. The crop often escapes rust injury altogether, but when attacked, the development of the kernel will have so advanced that the loss will not be serious.

7. Early Varieties. An early maturing variety of equal value and yield to the Red Fife and Marquis wheat is yet to be discovered. The use of early varieties is recommended, if they are satisfactory as regards yield and quality. Prelude wheat ripening some 10—15 days earlier than Marquis, has almost entirely escaped serious rust injury, but cannot be generally recommended where Marquis and Red Fife can be grown and yet in 1916 it saved many farmers from incurring considerably greater losses.

Marquis wheat matures earlier than Red Fife and from the standpoint of rust-escaping is much to be preferred. It yielded much better last year than Red Fife on account of its more early maturity, thus in a measure escaping the rust.

It will be seen that earlier maturity may save the crop, therefore early sowing and the use of early varieties or any cultural operation hastening maturity, are most strongly recommended.

8. The Barberry. This shrub has no place near grain fields or in grain-growing regions, and should, therefore, be exterminated, since it is just as much a contributory factor to grain rust, as late sowing and others over which we can exercise control.